(54) **Gun fire control systems**

(57) A gun fire control system comprises a first memory (15A) operable on receipt of a true range value from a rangefinder (16) to output the corresponding standard ballistic range value. A second memory (15B) is pre-programmed with correction coefficients (A, B, M, N) delivered to a calculator (15C) together with an operator correction value (COR) (from buttons 14A, 14B). Calculator (15C) operates to establish air density and charge temperature parameter corection changes (Δ AD, Δ CT) and delivers these changes to calculator/store (15D) which updates and stores parameter values (AD, CT). An arithmetic unit (15F) evaluates a range correction factor from the data available from memory (15B) and unit (15D) at the ballistic range established by memory (15A). This range correction factor is combined with the ballistic range established by memory (15A) in unit (15G) and the corrected ballistic range made visibly available in display (11) to the operator.
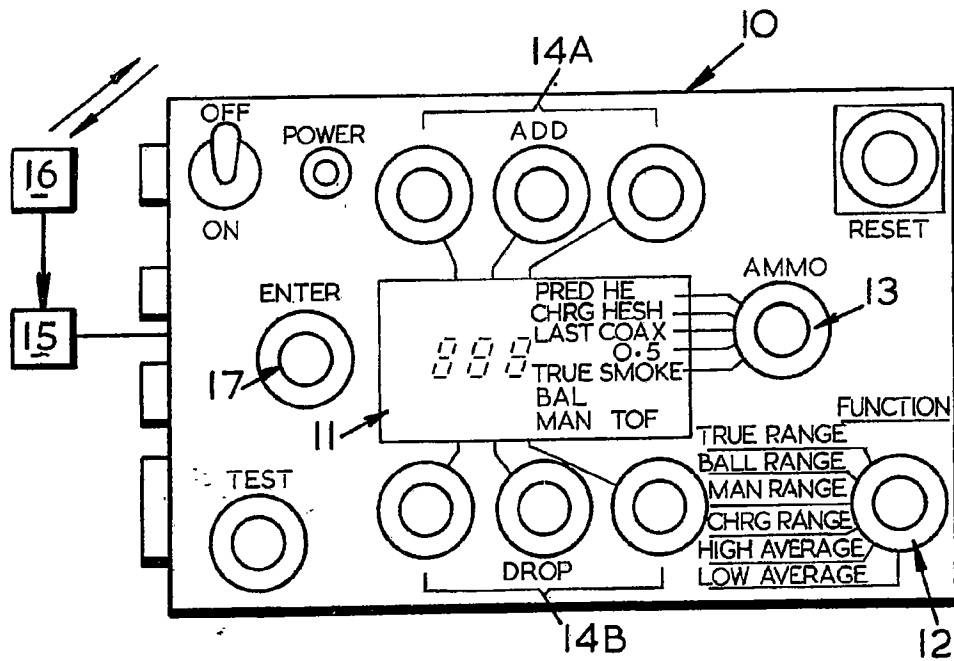
FIG. 2

FIG . 1

MANUAL RANGE

LRF 16

TRUE
RANGE

OPERATOR ADJUSTMENT

15C

CAL Δ AD
Δ CT

TIMER 15H

AMMO
SELECT

CT

13

RANGE
CONVERT
TRUE
TO
BALL

STORE
A B M N
FOR HIGH
AND LOW
RANGES

CALC &
STORE
AD, CT

15D

15A

15B

CALC & STORE
HIGH & LOW
COR & AVES

15E

EVALUATE CORRECTION
FROM
AD (A.R + B) + CT (M.R.+ N)

H COR.
&
L COR
AVES

15F

15G

CORRECTION

ADD

15

DISPLAYED
BALLISTIC
RANGE

17

12

FUNCTION
SELECT

ADD / DROP

11

DISPLAY

14

FIG. 2

SPECIFICATION
Gun fire control systems

This invention relates to gun fire control
systems.
5   Known gun fire control systems incorporate a
rangefinder for assessing target range and a gun
sight for viewing the field of view in which the
target is located. The gun sight incorporates a
computer controlled aiming mark or a graticule
10   calibrated with range markings specific to a
particular form of ammunition (e.g. HESH) and
relative to the gun barrel axis. The graticule
calibrations, being non-adjustable, are correct only
for a particular set of gun-barrel parameters (gun
15   barrel wear and bending) and atmospheric
parameters (such as temperature, pressure and
humidity). Unfortunately these parameters are not
constant and, if a hit is to be achieved on the
target, it becomes necessary to depart from the
20   specific graticule range marking relevant to the
measured target range by an amount dependent
upon the cumulative variation in the aforesaid
parameters. Traditionally this departure has been
assessed on a trial and error basis by the gunner
25   firing one or more preliminary shots but, more
recently, the fire control system has incorporated a
computer receiving input signals from parameter
sensors and outputting an aiming mark to the
sight graticule. This computer requires to be fairly
30   powerful since the conventional ballistic equations
which it utilises are relatively complicated and the
atmospheric parameters referred to are
determined by environmental sensors which, in
the case of tanks and the like, are external to the
35   armour plating thereby constituting a weakness
both as regards impenetrability of the armour
plating and as regards viable operation of the
system when under attack, since enemy
ammunition may penetrate the armour plating at
40   the site of the environmental sensors and/or
disable these sensors. A further disadvantage of
the known systems is that whereas it is a simple
matter for the gunner to change the type of
ammunition in use (say from HESH to COAX or to
45   HE) the sight graticule cannot be readily changed
and consequently the effectiveness of the systems
becomes reliant solely upon the computer
generated aiming mark, and the need to
programme the computer with data relevant to
50   each possible type of ammunition further
emphasises the requirement for a powerful
computer.
     Recently there has been introduced a gun fire
control system comprising a sight graticule with a
55   standard ballistic scale relating range with gun
elevation and a computer arranged to correlate true
target range with the ballistic scale range for each
of a plurality of different types of ammunition, the
computer being operable on receipt of a true
60   range value to establish and display a range value
on the ballistic scale effective to provide the gun
elevation required for a selected type of
ammunition. The computer is preprogrammed and
permits the gunner to change the type of

65   ammunition in use and be provided by the fire
control system with a displayed range value
which, if the same graticule range value is
superimposed on the target, will result in a target
hit provided the gun barrel parameters and the
70   atmospheric parameters are at their set values. If
these parameters have departed from their set
values the gunner can utilise the traditional
procedure for assessing and correcting for the
departure.
75   In order to correlate the true range value input
with the ballistic range value output it has been
proposed that the computer be provided with a
plurality of first sections respectively correlating
true range with gun elevation for each of a
80   plurality of different types of ammunition, a
second section correlating gun elevation with
range on the standard ballistic scale, and a
selector for selecting one of said first sections, the
true range input value being used as an address to
85   locate a gun elevation value in the selected first
section and the located gun elevation value being
used as an address to locate the range value on
the ballistic scale which is displayed. Alternatively,
it has been proposed that the computer be
90   provided with a single section incorporating a
plurality of coefficients, a set of such coefficients
being obtained from a look-up table in the
computer whose address is determined by
ammunition type and true range so that the
95   computer converts directly from true range to
ballistic range.
     The standard ballistic scale may in fact be
identical to that correlating true range with gun
elevation for a particular type of ammunition but
100 this need not be the case.
     The present invention provides an improved
gun fire control system wherein dependence upon
environmental sensors is reduced.
     According to the present invention there is
105 provided a gun fire control system comprising a
computer having a first memory preprogrammed
with true range to standard ballistic range
conversion data and operable on receipt of a true
range value to output the corresponding standard
110 ballistic range value from said conversion data, a
second memory preprogrammed with correction
coefficients, calculating means for evaluating air
density and charge temperature parameters
responsive to a manual range-correction input by
115 a system operator, means for evaluating a
correction factor utilising the parameter values
output by said calculating means, said standard
ballistic range value and the correction
coefficients stored in said second memory, and
120 means for combining the standard ballistic range
value and the correction factor to provide a
correction ballistic range value.
     The standard ballistic range conversion data
with which the first memory is preprogrammed
125 may be identical to that correlating true range
with gun elevation for a particular type of
ammunition but this need not be the case as has
been explained.
     Preferably said calculating means is operational

to evaluate increments in said parameters utilising the same algorithm as the correction factor evaluating means based upon said manual range-correction input at a particular true range value
5 and zero correction factor at a predetermined true range value. Conveniently said predetermined true range value is either a minimum or maximum range value, the selection being according to which is more remote from said particular true
10 range value.

The system may have a sight incorporating a graticule whose range markings correspond with those of the standard used in the conversion data in which case the corrected ballistic range value
15 provided by the determining means may be displayed visually in numeric form as a command signal to the operator so that he can thereafter superimpose the corresponding graticule marking on the target. Alternatively the sight may
20 incorporate a computer-controlled aiming mark, for example an ellipse, the position of which in the sight is determined by the corrected ballistic range value provided by the determining means and which is effective as a command signal to the
25 operator so that he can thereafter superimpose the aiming mark on the target. As is already known the size of the aiming mark may also be made inversely proportional to target range. It will be evident that the prior art discloses that the
30 operators command signal may be either in the form of an aiming mark or a range value and that the present invention which is concerned with the achievement of such a command signal in the absence of environmental sensors is equally
35 applicable to both forms of command signal.

An embodiment of the present invention will now be described by way of example with reference to the accompanying drawings, in which:
40 Fig. 1 illustrates part of the operator's control panel; and

Fig. 2 schematically illustrates the computer.

The panel 10 shown in Fig. 1 comprises a digital display 11 with a function selector switch
45 12 which determines the function whose value is displayed. Switch 12 can select true range or ballistic range or manual range or charge temperature or high correction average or low correction average. A selector switch 13 is
50 provided for identifying the type of ammunition in use, for example HE, HESH, COAX, 0.5, SMOKE and digit adjustment buttons 14A and 14B are provided for the operator to enter manually an adjustment to the displayed function, buttons 14A
55 being for incrementing and 14B for decrementing. The panel 10 is coupled to a local computer 15 which is also coupled to a laser rangefinder 16 and the operation of the system is such that the operator sets switch 13 to the selected
60 ammunition type and this information is automatically entered into computer 15. With function switch 12 at 'ballistic range' he operates the rangefinder 16 which is mechanically linked to the gun sight and thereby produces a true range
65 measurement to the target on which the gun sight

is trained. This true range indication is directly entered into computer 15 which outputs a standard ballistic range value which is displayed at display 11. This standard ballistic range value is
70 generated on a predetermined basis namely that, for the selected type of ammunition, and the particular graticule in the sight, all other parameters such as charge temperature, barrel wear, air density etc. are at standard values as a
75 result of which the true to ballistic range conversion data is predetermined and is stored in the computer in table form. The operator then elevates the gun sight until the graticule mark with the same numerical value as the value displayed at
80 11 is superimposed on the target. The gun is then fired and in the event of the shot landing short of or overshooting the target the displayed value at 11 is adjusted by the operator making a judgment on the magnitude and direction of the miss
85 relative to the target and entering that judgment in the display 11 via buttons 14A or 14B. The operator then adjusts the elevation of the gun sight until the new graticule value is superimposed on the target and then fires a second shot. This
90 procedure is repeated until the shot scores a hit on the target whereafter the computer 15 updates its information content as will be explained so that for a new target the ballistic range value output by the computer to the display 11 will be computer-
95 corrected and of sufficient accuracy to give a very high hit probability prior to the operator making a manual correction.

The computer 15 is of the microprocessor type and data is principally stored in table form so that
100 a true range value is used as an input to produce the corresponding standard ballistic range output value previously described. Additionally range correction data is stored to permit evaluation of correction factors based upon the realisation that
105 the principal parameters affecting ballistic range for a given gun and given ammunition type are charge temperature and air density.

We have established that a reasonable approximation to the correction factor for these
110 parameters is given by the formulae:

$$AD \, . \, (A \, . \, R + B) + CT \, . \, (M \, . \, R + N)$$

where AD is air density on a scale where standard air density is zero; CT is charge temperature on a scale where standard charge temperature is zero;
115 R is standard ballistic range; and A, B, M and N are coefficients which have first predetermined values for ranges (R) less than a predetermined range value and second predetermined values for ranges (R) equal to or greater than that predetermined
120 range value. For example, the predetermined range value may be 1500 meters (true range).

The computer 15 is arranged to operate so that commencing from a standard ballistic range when the operator fires a first shot at a particular
125 true range value and misses the target he assesses the manual range-adjustment required to achieve a hit on the target with a second shot, moves the gun to the adjusted ballistic range and

fires. If this second shot scores a hit the operator takes no more action at that stage. The operator's action in effecting the manual range-adjustment or correction on the display 11 is automatically fed
5 into the computer 15 which updates the correction data in a manner to be described so that the displayed ballistic range for all subsequent true range values will be of sufficient accuracy to provide a high probability of a hit with
10 minimal need for adjustment by the operator.

This is achieved by the computer 15 operating so that in the initial encounter any adjustment required to the standard ballistic range is effected solely as an air density parameter correction. Thus,
15 if the encounter is at a true range of 1000 meters and the first shot achieves a hit the air density parameter (AD) is maintained at zero for all subsequent engagements until the operator enters a further adjustment. If, however, the first
20 encounter requires a second shot to achieve a hit the operator's adjustment is entered into computer 15 which evaluates the air density parameter (AD) and this evaluated air density parameter is maintained for all subsequent
25 engagements until the operator enters a subsequent adjustment. This evaluation is effected from the equation:

$$\text{operator's adjustment} = AD . (A . R + B)$$

and all parameters except AD are known.
30 The foregoing discussion is based upon there being no change required to the charge temperature parameter (CT), and it will be appreciated that CT can be set initially either to zero or to a non-zero level but even in the latter
35 event the air density parameter AD can still be evaluated since the factor $CT . (M . R + N)$ is known.

It will now be understood that the result of the first engagement is to evaluate all variable
40 parameters in the equation:

$$\text{displayed ballistic range} =$$

$$\text{standard ballistic range} +$$

$$AD . (A . R + B) + CT . (M . R + N).$$

In the event of a subsequent encounter leading
45 to an operator's adjustment being entered into the computer 15 the system is arranged to operate so that both the AD and CT parameters are re-evaluated, in a manner to be explained, and the re-evaluated levels thereafter maintained for all
50 ranges until the operator makes a subsequent adjustment. Suppose, by way of example, that the next adjustment is required at a true range value of 2000 meters it is then evident that the operator's adjustment C_1, for the range $R_1 = 2000$
55 meters is given by the equation:

$$C_1 = \Delta AD (A . R_1 + B) + \Delta CT (M . R_1 + N)$$

where ΔAD is the change required to the

parameter AD, and ΔCT is the change required to the parameter CT. To solve this equation the
60 computer 15 is programmed to note that R_1 ($= 2000$ meters) is greater than the range 1500 meters and to then apply the equation:

$$C_o = 0 = \Delta AD (A'R_o + B') +$$

$$\Delta CT (M'R_o + N')$$

65 where $R_o = 500$ meters. That is, that the required correction C_o at the 500 meter range (which is a predetermined range value) is zero. The computer 15 therefore has two equations with two unknowns, ΔAD and ΔCT, and these can therefore
70 be evaluated by the computer using standard algebraic techniques so that the new values of AD and CT can be determined.

If any subsequent adjustment is required at a range less than 1500 meters a similar calculation
75 is performed by the computer 15 using $C_o = 0$ for $R_o = 2500$ meters (which is a predetermined range value).

It will be appreciated that $AD_n = AD_{n-1} + \Delta AD$ and that $CT_n = CT_{n-1} + \Delta CT$ where the subscript
80 n—1 denotes the previous value and subscript n denotes the new value. In the foregoing description the previous values of AD_{n-1} and CT_{n-1} have been the previously computed values.

It will now be appreciated that in order to
85 calculate ΔAD and ΔCT the computer 15 utilises an estimated correction C_o at one of two predetermined range values, depending upon which is more remote from the particular true range value. In the previous discussion we have taken
90 $C_o = 0$ but we also evaluate corrections (COR) at the predetermined range values and in predetermined circumstances use the average of the previous three evaluations. That is when the true range is below 1500 meters we evaluate by
95 the computer COR at 500 meters for each of the operator's adjustments, store these evaluations, and determine the average of the last three such evaluations (low correction average or LCOR). Likewise when the true range is 1500 meters or
100 greater we evaluate by the computer COR at 2500 meters for each of the operator's adjustments, store these evaluations, and determine the average of the last three such evaluations (High correction average of HCOR). These evaluations
105 and updating of HCOR and LCOR are effected automatically by the computer 15 from the information stored therein on receipt of each signal from rangefinder 16 and prior to the computer re-evaluating AD and CT in
110 consequence of an operator's adjustment. Prior to three evaluations of HCOR and LCOR we can utilise the average of only two HCOR and LCOR evaluations or we can utilise HCOR and LCOR averages imported from another similar fire
115 control system and it is for this reason that function selector switch 12 has 'high average' and 'low average' functions. That is, the HCOR average and the LCOR average can be read out from computer 15 and displayed at 11 for export to

another similar fire control system and imported
HCOR and LCOR averages can be dialled onto
display 11 (using buttons 14) and entered into the
computer 15 by setting selector switch 12
5 appropriately and actuating buttons 14.
 These high and low range average values are
retained in a protected store of the computer 15
and are utilised to calculate the initial values of AD
and CT in a 'restart' mode which ensues
10 automatically if the time elapsed between
successive true range readings received by the
computer exceeds a predetermined value (for
example one hour). The true range value received
(after one hour) enables the computer 15 to use
15 the high and low range average values HCOR and
LCOR to determine AD and CT. Also the 'restart'
mode ensues automatically if the true range value
received does not lie in the same low or high
range interval as the preceding true range value.
20 Fig. 2 schematically illustrates the format of the
computer 15 in greater detail and additionally
shows the connections of components 11, 12, 13,
14, 16 and 17 thereto. Computer 15 comprises
memory 15A storing values of standard ballistic
25 range which are accessed by values of true range
as determined by rangefinder 16; memory 15B
stores values of the coefficients ABM and N for
both high range and low range, memories 15A
and 15B (which although illustrated separately
30 may be physically integral) storing the appropriate
values for each of the different types of
ammunition and the appropriate set of such values
being accessed by means of switch 13. Block 15C
is an arithmetic unit organised to calculate ΔAD
35 and ΔCT as previously described and block 15D
calculates the parameters AD and CT as previously
described, preferably using the high and low
average values of HCOR and LCOR as calculated
and stored by block 15E. Block 15F is an
40 arithmetic unit which evaluates the correction
factor using the formula

AD. (A.R + B) + CT (M.R + N)

and this is added by adder 15G to the standard
ballistic range value R and fed via the selector
45 switch 12 to the display 11. The adjustments
input by the operator are effected by block 14, via
display 11 and routed according to selector switch
12 to block 15C. Manual entries of HCOR average
and LCOR average are effected according to the
50 position of selector switch 12 respectively to block
15E and manual range is entered to memory 15A
on pressing the enter button 17, and charge
temperature CT to block 15D.
 The 'restart' mode is detected by timer 15H
55 which on elapse of a predetermined time interval
from receipt of a range value from the
rangefinder controls block 15D to erase the stored
values of AD and CT and to calculate new values
of AD and CT using the high and low averages
60 from block 15E.
 In the foregoing description we have referred to
an operator and we wish it to be understood that
this term may embrace more than one individual

person such as is the case when the fire control
65 system is incorporated in a tank where some of
the operator's duties are undertaken by a gunner
and other duties are undertaken by a commander.

CLAIMS
 1. A gun fire control system comprising
70 means for presenting a displayed range value to
a system operator,
 manually-operable means for providing a range
correction input by a system operator as a
measure of the extent by which a projectile misses
75 a target sighted according to the displayed range
value,
 a rangefinder, for establishing a true range
value to the target,
 first memory means preprogrammed with true
80 range to standard ballistic range conversion data
and operable on receipt of a true range value to
output the corresponding standard ballistic range
value from said conversion data,
 second memory means preprogrammed with
85 preset correction coefficients.
 first calculating means for evaluating air density
and charge temperature parameters according to
the outputs of said manually-operable means, said
first memory means and said second memory
90 means,
 second calculating means for evaluating a
correction factor utilising the parameter values
evaluated by said first calculating means, the
standard ballistic range value output by said first
95 memory means and the correction coefficients
from said second memory means,
 combining means for combining the standard
ballistic range value output by said first memory
means and the correction factor output by said
100 second calculating means to provide a corrected
ballistic range value for delivery to said presenting
means and against which to sight the target for
firing a subsequent projectile.
 2. A fire control system as claimed in claim 1,
105 wherein said second memory means is
preprogrammed with sets of correction
coefficients respectively pertaining to different
projectile types, the operable set being identified
by a manually-operable selector switch.
110 3. A fire control system as claimed in claim 2,
wherein each set of correction coefficients
comprises a plurality of subsets respectively
applicable to ballistic range values within a
plurality of range intervals, the operable subset
115 being identified by the ballistic range value output
by said first memory means.
 4. A fire control system as claimed in any
preceding claim, wherein said second calculating
means evaluates said correction factor (COR)
120 according to the algorithm

COR   = AD (A . R + B) + CT (M . R + N)

where

AD   = air density parameter value
CT   = charge temperature parameter value

A,B,M,N   = preset correction coefficients
R   = standard ballistic range.

5. A fire control system as claimed in claim 4,
wherein said first calculating means evaluates said
5 parameters according to the said algorithm by first
identifying the range interval encompassing the
standard ballistic range for a given target and then
identifying a predetermined range value in a
different range interval at which the correction
10 factor is preset so as to establish a first equation
with two unknowns, a second equation with two
unknowns being established by the operator-
applied correction at the identified standard
ballistic range, said two equations being solved to
15 evaluate said two parameter values.
6. A fire control system as claimed in claim 5,

wherein the two unknowns evaluated by said two
equations are parameter correction values and
these are combined with the previous parameter
20 values which are stored in up-dated form.
7. A fire control system as claimed in claim 6,
wherein said preset correction factor is computed
as the average of a plurality of correction factor
evaluations according to said algorithm at the
25 predetermined range value within the range
interval encompassing the standard ballistic range
for a plurality of targets, such evaluations being
subsequent to evaluation of the updated
parameter values pertaining to the respective
30 targets.
8. A gun fire control system as claimed in claim
1 and substantially as hereinbefore described with
reference to the accompanying drawings.